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AUTHOR	Bentley, Michael L.; Alouf, James L.
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ABSTRACT

Because research has found that many students experience science as fragmented, this study examined the impact of modeling by science teachers during faculty development programs on participants' subsequent classroom instruction and on their students' science achievement and motivation. In two programs, liberal arts college science professors implemented inquiry-based activities for classroom teachers, teaching science content to teacher participants using hands-on/minds-on lessons. Surveys of participants from three iterations of these programs solicited their observations about their own post-project teaching methods and the impact they perceived in students' science achievement and motivation as a result of experiencing inquiry teaching. Teachers in both groups, for the most part, were using inquiry-based science activities once a week or less than once a week, and there were some gains in students' academic achievement. The categories of achievement where teacher perceived the most gain were teacher-made exams, hands-on activities, student problem solving, and recall of content. Participant comments suggested that teachers believed students remembered the content better and could use the information to solve problems, especially on teacher-made tests. Results indicated an overwhelmingly positive effect on student motivation. The survey is appended. (Contains 22 references.) (SM)

The Influence of the modeling of inquiry-based science teaching by science faculty in P-12 teacher professional development programs

A paper presented at the 2003 annual meeting of the
American Association of Colleges for Teacher Education
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Michael L. Bentley, EdD
Associate Professor, Science Education
University of Tennessee
Department of Theory & Practice in Teacher Education
404A Claxton Complex, Knoxville, TN 37996
mbentle1@utk.edu

James L. Alouf, PhD
Chair and Professor of Education
Sweet Briar College
Department of Education, Gray 302
Sweet Briar, VA 24595
alouf@sbc.edu

Introduction

An inquiry approach to teaching p-12 science is strongly advocated in all of the major national curriculum reform projects in the U.S. of the past decade, including the National Research Council's National Science Education Standards (NRC, 1996) and the American Association for the Advancement of Science's Project 2061 (AAAS, 1993), as well as in the science curriculum documents of many countries (Ministry of Education, 1993; DfEE, 1999; Curriculum Corporation, 1994). However, an inquiry approach was seen as the ideal for classroom practice several decades before these documents. George DeBoer (1991) in his history of science education, states,

> If a single word had to be chosen to describe the goals of science educators during the 30-year period that began in the late 1950s, it would have to be *inquiry*. Inquiry teaching was intimately associated with the NSF curriculum projects and was view long afterwards as an educational ideal worth striving for, even if that striving was often unsuccessful. (p. 206)

Robert Yager (1997), an elder statesman in the science education profession, also notes: "Inquiry was a major focus for the reform efforts of the 60s. ...During the two decades following Sputnik, two billion dollars were used in the United States to reform school science - almost always with an emphasis on 'inquiry.'"

While inquiry teaching is indicated as a curriculum goal in the various framework documents of the states, including Virginia's *Standards of Learning* (Board of Education, 1995), George Nelson, director of AAAS's Project 2061 recently claimed, "Most state standards still envision science education as the accumulation of almost random facts rather than the development and application of concepts and skills." (*NSTA Reports!*, 2001-2002, p. 1).

Despite widespread acceptance of inquiry teaching by science educators since World War II, inductive methods have never really achieved primacy over the traditional approach (expository teaching or direct instruction), which reemerged with force during the conservative backlash of the 1980s. While leaders in the field of science education and science teacher educators continue to promote inquiry teaching, traditional didactic expository instructional methods, such as teacher-centered whole-class lecture and textbook-based read-about-science activities still make up much of the science instruction in American classrooms. This approach is narrowly aimed at preparing children academically for standardized tests or for the next grade or level (Grossen, Romance, & Vitale, 1994; Bentley, Ebert & Ebert, 2000; Rescher, 2000).

In addition to the failure of inquiry methods to find widespread acceptance, science textbooks have also been cited as a reason for problems with inquiry adoption. Criticisms have been made of science textbooks including overloaded with content, emphasizing coverage over depth of understanding, limiting investigations to cookbook labs, failing to connect the science concepts to students' experiences, and also failing to produce conceptual change (Newport, 1990; Smith, Blakeslee, & Anderson, 1993). Because of the textbook dominance of science lessons, many children still have few opportunities to learn science through inquiry. Even when teachers do "hands-on" science in their classrooms, the activities are often cookbook-type labs rather than open-ended investigations. Because of the way they are taught, students may come to perceive science to be the information found in textbooks and scientific processes to be the verification activities found in the "hands-on" activities that they occasionally carry out.

In their noted study of the adolescent years, Csikszentmihalyi, Rathunde, & Whalen (1993) found that many students experience science as fragmented: "Such students feel they are showered with decontextualized dates, names, discoveries, and ideas that make little immediate sense to them." (p. 118) These researchers also observed that, compared to their colleagues in other disciplines, many science teachers were more authoritarian, placing greater emphasis on external control and long-term instrumental goals.

One approach to address this situation has been to provide professional development activities for p-12 teachers focusing on the use of indirect methods, including inquiry teaching. The presenters evaluated recent professional development programs designed for Virginia teachers by two private liberal arts colleges funded by the Dwight D. Eisenhower Professional Development Program of the U.S. Department of Education. In these programs science faculty modeled inquiry-based science teaching. That is, biology (chemistry, physics, etc.) professors taught science content to teacher participants using "hands-on/minds-on" lessons. Our interest is to describe and analyze survey data about the impact of modeling by science faculty on participants' subsequent classroom instruction and on their students' science achievement and motivation in science. We hope our findings will contribute to the discussion of the value of this modeling approach in promoting inquiry science teaching among teachers.

Inquiry teaching and professional development

The meaning of "science as inquiry," one of eight content standards in the National Science Education Standards (NSES), has been delineated by the National Academy of Sciences (Committee on Development of an Addendum, 2000). In the NSES, scientific inquiry refers, on the one hand, to the multiple ways scientists study nature and propose explanations for phenomena based on the evidence they derived in their studies. On the other hand, in the classroom, inquiry refers to the activities in which children develop understandings of scientific concepts and of how scientists conduct their studies. Inquiry also is an approach to teaching in which children themselves are enabled to conduct scientific inquiry. The National Science Education Standards state that as a result of school activities all students should develop abilities necessary to do scientific inquiry, as well as develop an understanding about scientific inquiry (NRC, 1996). DeBoer (1991) points out that inquiry teaching is also referred to as heuristic teaching and discovery learning, and also as teaching by the problem solving method. He elaborates further:

> ... inquiry teaching also came to be associated with a particular method of teaching - a method of teaching not only the processes of science but also the concepts of science. Inquiry teaching came to be associated with a set of instructional practices and beliefs about learning that are generally referred to as inductive in nature. Inductive approaches are based on the premise that students can be inquirers in the classroom and generate meaning more or less independently by examining a variety of available learning materials. (p. 207)

Inductivist approaches are frequently presented and demonstrated in P-12 teacher education courses and in professional development programs offered to practicing teachers. However, students in teacher licensure programs have diverse academic backgrounds in science, and for those seeking to become elementary teachers this background is often minimal. Typically pre-service elementary teachers have taken two to four tertiary-level courses in the natural sciences. Furthermore, these science courses, especially at the institutions where introductory level undergraduate classes are large, are likely to be lecture-textbook dominated and so crammed with content detail that the idea of science as inquiry is rarely introduced or developed. Since the beliefs that teachers hold about the nature of science and science teaching and learning play an important role in their classroom decisions and practices (Bradford & Dana, 1996), participation in professional development programs in which the inquiry approach is not only advocated but modeled by science faculty may influence subsequent choices teachers make in providing classroom science activities for students.

In the professional development programs we investigated at two small private liberal-arts institutions in Virginia, the major instructional focus was inquiry science teaching as modeled by science faculty. These programs were funded in part by the Dwight D. Eisenhower Professional Development Program of the U.S. Department of Education. In this study, we examined the impact of these programs on subsequent teacher-participant choices of classroom activities. Did the modeling of inquiry-based science teaching by college science faculty make a difference in the science programs teacher-participants enacted in their classrooms following the in-service?

Description of the Projects

The two professional development projects we investigated focused on inquiry teaching in science education. In both projects liberal arts college science faculty implemented inquiry-based activities for classroom teachers (primarily elementary and middle school teachers). We surveyed participants from three iterations of such a program at one Virginia institution, Sweet Briar College, and of one program at another institution, Hollins University. Both projects were supported by grants from the Dwight D. Eisenhower program, administered by the State Council of Higher Education of Virginia (SCHEV).

The Hollins University Professional Development Project

Hollins University is an independent liberal arts college for women located on a 475-acre campus in Roanoke, Virginia, a metropolitan area of 230,000. Hollins offers a liberal arts program for undergraduates and licensure and master's degrees in education. The Hollins Active Learning in Elementary Science project held a two-week intensive summer session in June 2002 and a final all-day session in mid-October. Twenty-five teachers in grades 4-6 participated in the summer institute where content in life, physical, and earth-space science specified in the Virginia Standards of Learning (Board of Education, 1995) and in the National Science Education Standards (NRC, 1996) was presented. Hollins science faculty and Virginia Museum of Natural History scientist/curators conducted sessions addressing major science concepts using a hands-on, inquiry approach. The program also focused on active learning strategies (Harmin, 1998), integrated curriculum, and differentiated instruction (Tomlinson, 1995). Contributing scientists and the project director also addressed the nature of science as grades 4-6 curriculum content. Community resources and technology in the classroom science program were also program aspects. A communication network and Institute web site (http://www1.hollins.edu/classes/hesit/homepage.htm) was created to provide ongoing resources for participants and other teachers.

The Sweet Briar College Professional Development Project

Sweet Briar College is an independent liberal arts college for women located on 3,300 acres twenty miles north of Lynchburg, Virginia. The first professional development project began in the summer of 1999 when college science faculty won the first of three Eisenhower grants to teach inquiry-based, hands-on science workshops for teachers in central Virginia. The first summer workshop offered participants the chance to experience twenty chemistry modules that were linked to the Virginia Standards of Learning in grades 6-12. In the summer of 2000, the Eisenhower workshops offered twenty-five hands on activities in chemistry, biology, and physics to teachers in grades 4-8. The latest iteration of the Eisenhower workshops in the summer of 2001 offered teachers in grades K-8 a broad range of hands-on activities in chemistry, biology, environmental science, and mathematics. In each of the years following a summer institute, teachers were invited to return for one-day workshops as a way of continuing teacher engagement in hands-on science. As part of each Eisenhower grant, teachers were given laboratory equipment that could assist them in conducting experiments with their own students.

Method

We used participant questionnaires to survey teacher observations following their participation in either of the professional development projects at Hollins University or Sweet Briar College. We asked a series of questions (see appendix) to solicit participants' observations on their own post-project teaching methods, or approach, and the impact they perceived in student achievement in science and motivation as a result of experiencing inquiry teaching. From this data, we can infer something of the impact of the inquiry-oriented professional development projects on teacher participants and their students' science learning.

Results

The survey data are displayed in the bar graphs below. Figure 1, a (for the Hollins cohort) and b (for the Sweet Briar cohort) show the teachers' responses when we asked how often they use inquiry-based activities in their classrooms. Most respondents in both groups use inquiry activities once per week or less. Note, however, the comment made by one elementary teacher of 15 years in regard to this question:

I marked 'less than 1 per week' on #1. I felt it was hard using the given choices – I try to do something inquiry based with each unit we study – these usually take at least 2 class lessons to complete. I also like to do unrelated activities between units – many of these last more than one class session.

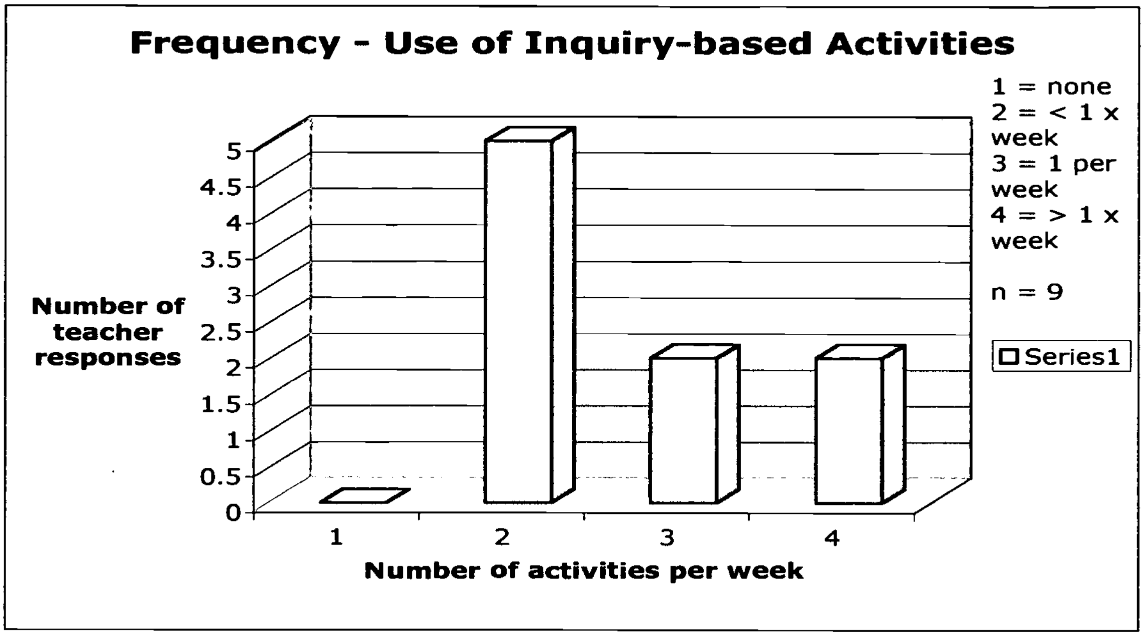

Figure 1 (a) Responses of Hollins project participants

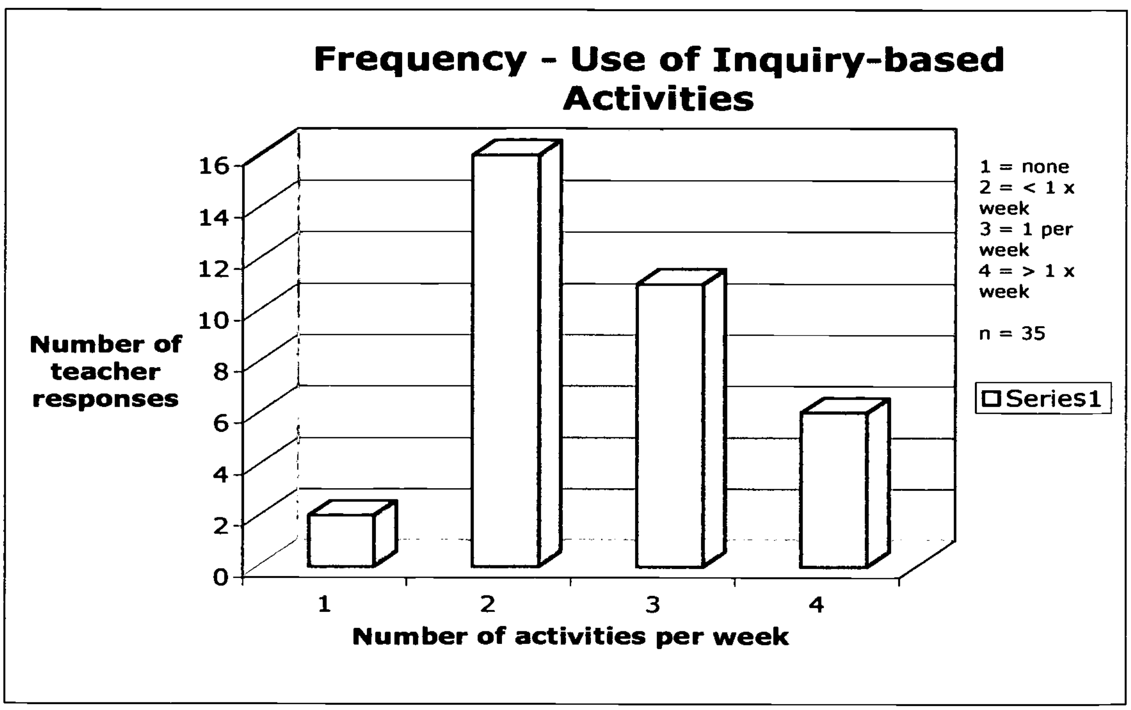

Figure 1 (b) Responses of Sweet Briar project participants. One survey had no response to this item.

Figure 2, a (for the Hollins cohort) and b (for the Sweet Briar cohort) show the teachers' responses when we asked if they have perceived student achievement gains as a result of the use of inquiry-based activities. Respondents in both groups perceived gains, with most indicating "some gains."

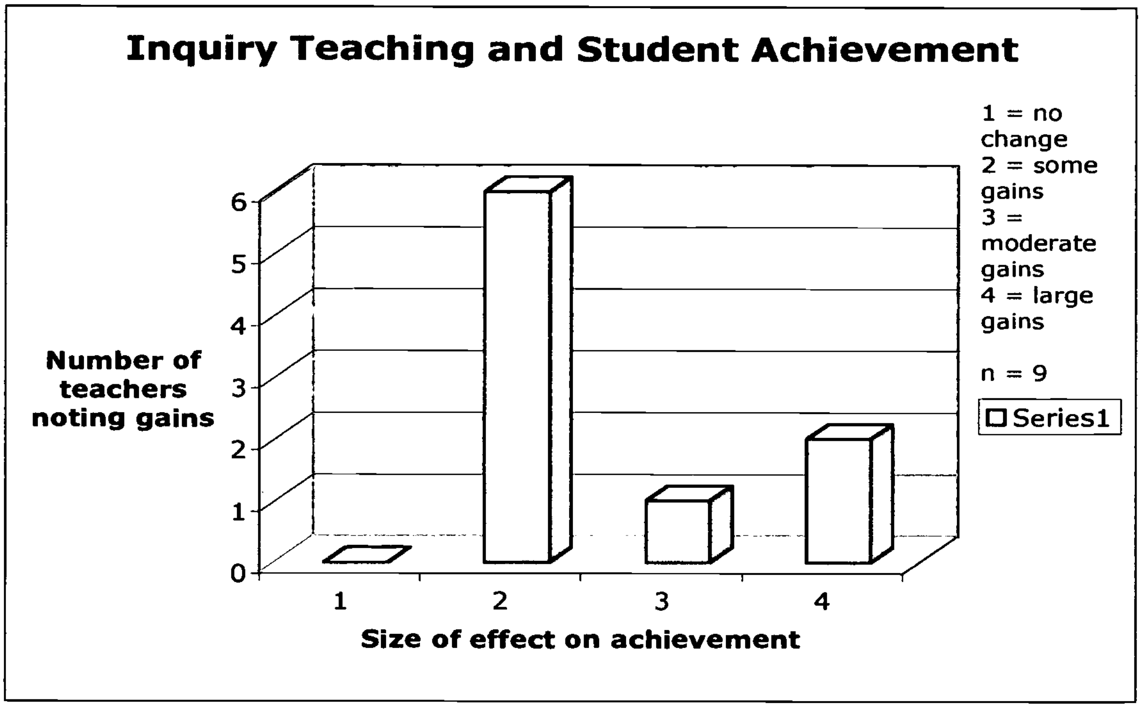

Figure 2 (a) Responses of Hollins project participants.

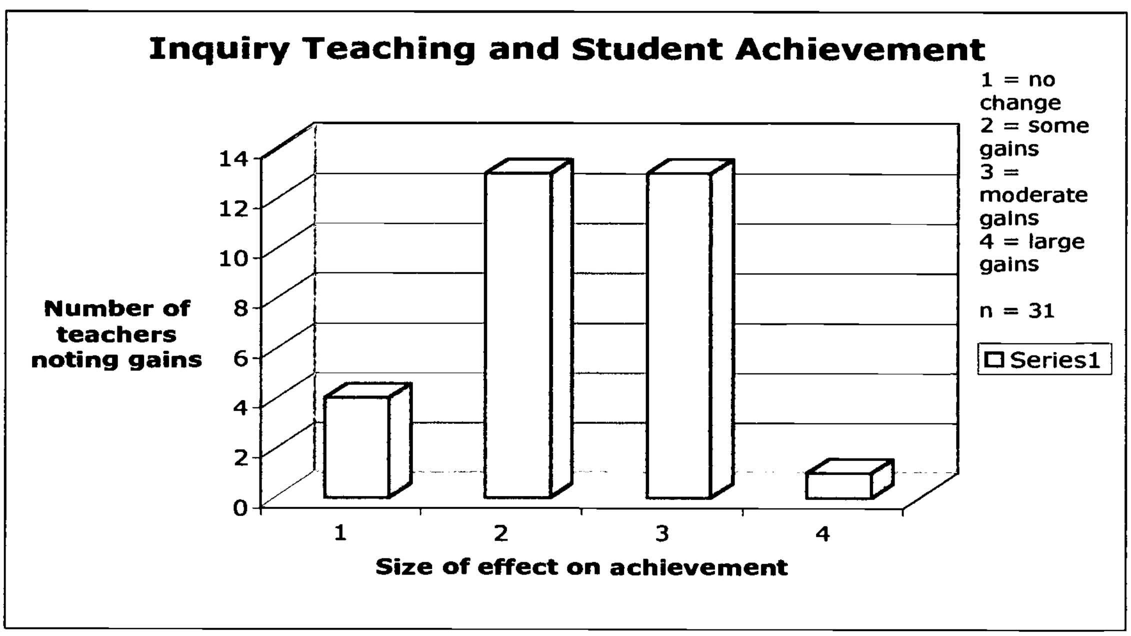

Figure 2 (b) Responses of Sweet Briar project participants. Five surveys had no response to this item.

Figure 3, a and b show the teachers' responses when we asked them to name the ways in which they found their students' achievements in science had improved. Most respondents in both groups noted several forms of achievement gains.

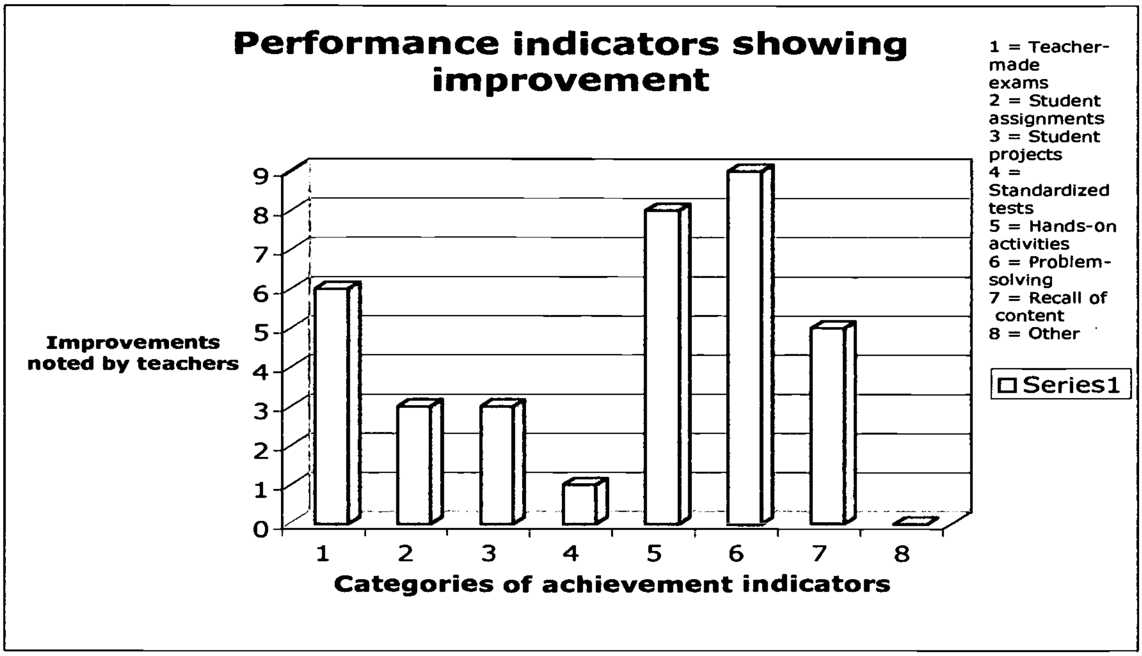

Figure 3 (a) Responses of Hollins project participants.

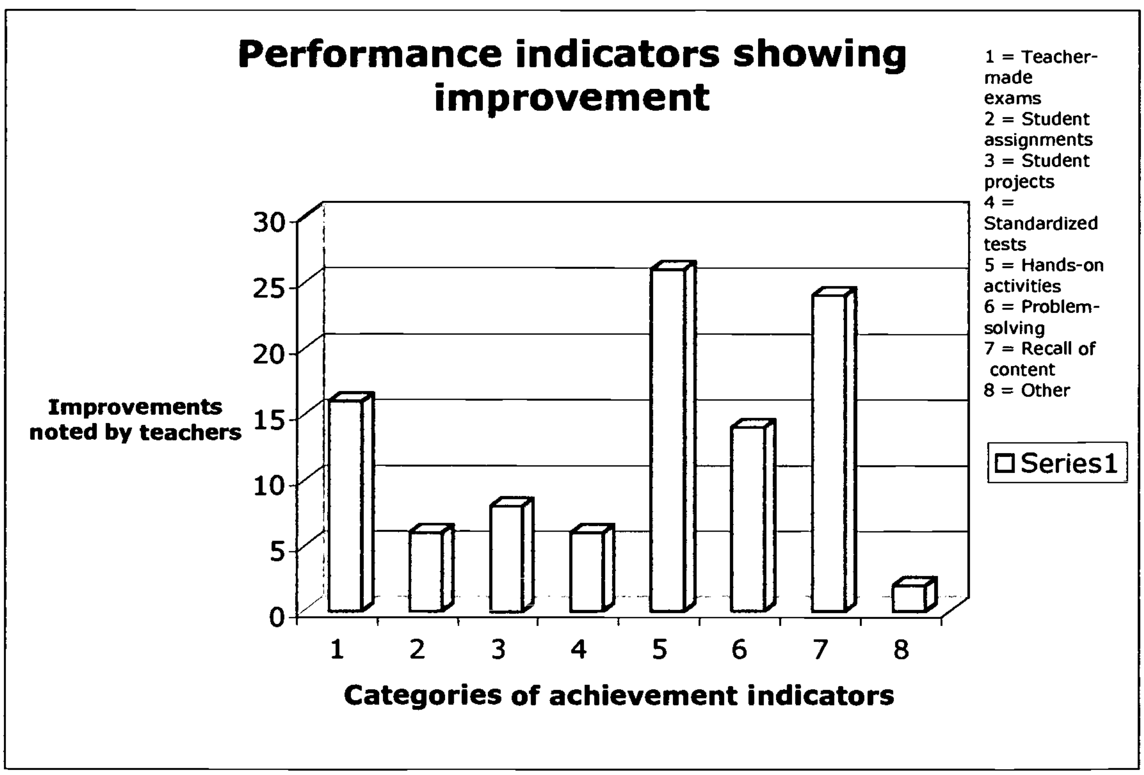

Figure 3 (b) Responses of Sweet Briar project participants.

Figure 4, a and b show the teachers' responses when we asked them how inquiry-based teaching has affected student motivation in their classrooms. Most indicated they found more student receptivity to learning.

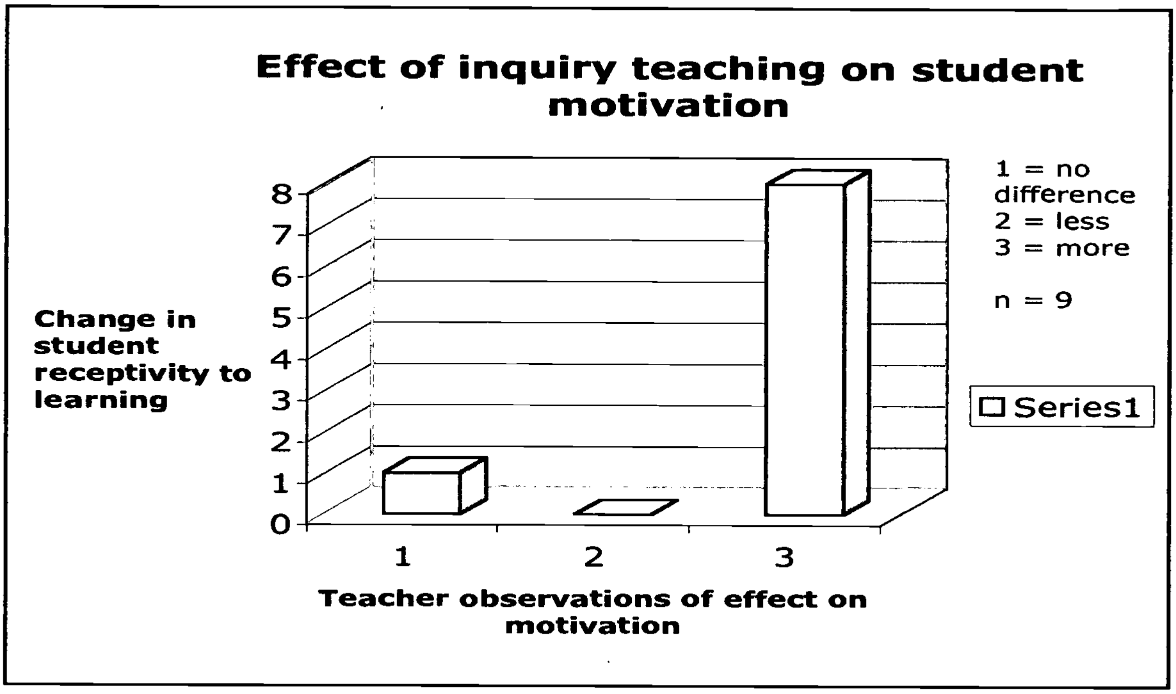

Figure 4 (a) Responses of Hollins project participants.

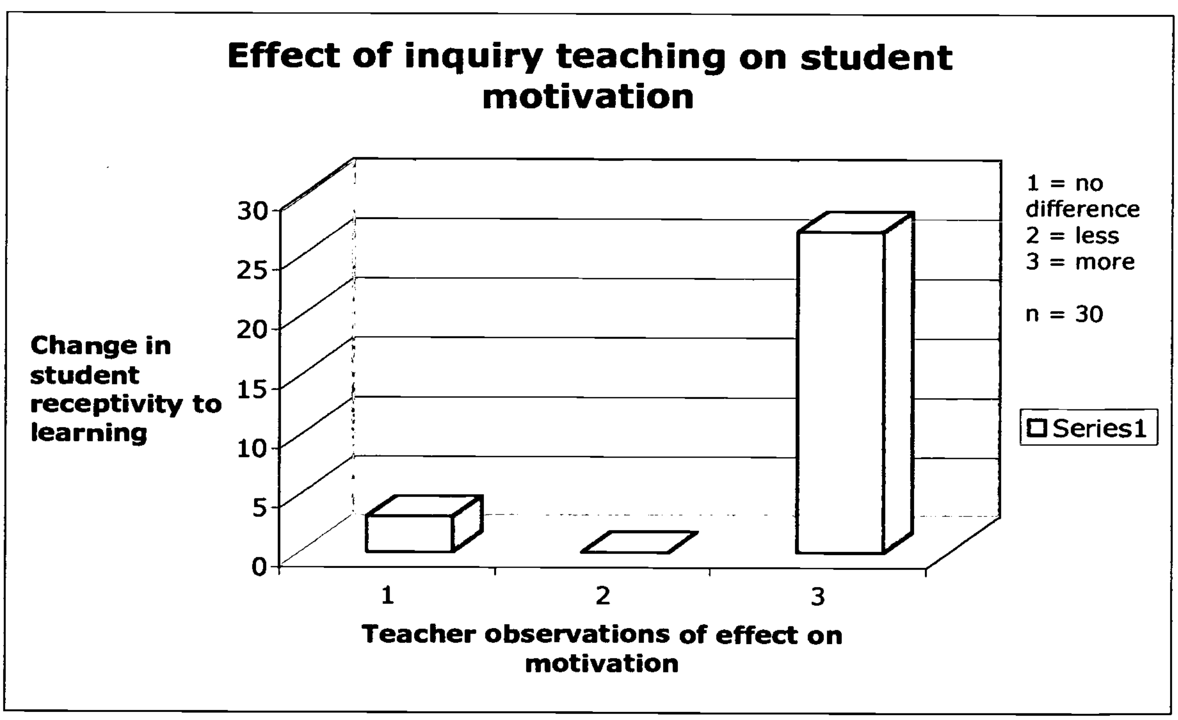

Figure 4 (b) Responses of Sweet Briar project participants. Six surveys had no response to this item.

Discussion of results

Survey findings from this study are limited by several factors. Although both the Hollins and Sweet Briar teacher participants were surveyed with the same instrument, the groups experienced different inquiry-based programs. In addition, those teachers surveyed from the Sweet Briar group were actually participants from inquiry-based programs spanning a three-year period. The researchers made no attempt to control for differences in the programs, focusing instead on the findings from both programs that affect student achievement. An examination of bar graphs of the data demonstrates findings of some interest to the researchers, given the standards-driven environment dominating p-12 public education in Virginia. Because of the limitations of this study, we make no claims to generalizability. We do think, however, that these findings warrant some attention in the professional community because they describe trends in teacher perceptions of student achievement when inquiry-based science instruction is modeled and implemented in p-12 classrooms. The response sample is predominately elementary teachers in both the Hollins and Sweet Briar cohorts, with some middle school teachers responding in the Sweet Briar group. A sample of the instrument used in this study may be found in the appendix.

In the Hollins cohort, 9 participants out of 22 responded to the survey, a return rate of 41%. In the Sweet Briar cohort, 36 participants out of 126 responded to the survey, a return rate of 29%. Proximity to the professional development institutes and timing of the survey (December, 2002) may have contributed to the poor rate of return in the Sweet Briar cohort.

The bar graphs indicate that teachers in both groups, for the most part, are using inquiry-based science activities once a week or less than once a week and that they have noted some gains in student achievement. The categories of student achievement where teachers perceive the most gains are: teacher-made exams, hands-on activities, student problem-solving, and recall of content. The researchers found the last category surprising since inquiry-based instruction is usually linked with process rather than content learning. The participants' comments, however, indicated that teachers believed that students remembered the content better and could use the information to solve problems, especially on teacher-made tests. As one middle school teacher of 32 years reported:

> Our SOL scores have increased in science. I review students for tests and they know more answers and do better on test scores. Just this last week, gave the students a section of a chapter on work. The majority of the students could use and get the correct answers for problems on work and power.

She continued to note that her students "did not need prodding" or "needed very little help" in calculating problems and were adept at picking out important information in chapters.

An elementary teacher of 35 years commented that, "Students understand concepts better after doing inquiry-based activities. The concepts have more meaning to them. The students take ownership and feel they have discovered and made conclusions on their own." Another elementary teacher, this one with 15 years experience, noted, "I feel inquiry based teaching helps each student really understand the concepts, helps them build self-confidence, and helps them enjoy science!"

While these comments are reflective of the impact of inquiry-based teaching on student learning, our results clearly indicate an overwhelmingly positive effect on student motivation. For instance, in the Sweet Briar cohort 25 out of 35 responses to the question concerning the impact of inquiry on student motivation (#5) stated that their students were more receptive to learning. An elementary teacher with 4 years experience stated, "Students are eager to participate, anticipate coming to science class with pleasure, and have been motivated to extend and continue their learning outside the classroom." These results support findings that hands-on learning positively impacts students' motivation to learn.

Teachers also cited no observed negative effects on student achievement. When negative comments were offered, they were not directed to student outcomes. A few respondents made negative comments about the difficulty of implementing inquiry-based science with large numbers of students or they cited the lack of funds and equipment as a difficult problem to surmount. One elementary teacher of 26 years did report, "At times, students will remember doing something investigative but don't remember why or the total concept. They remember the foods, the water and sponges, the egg, but not plate movement in three ways or density concepts." While the teacher comments were directed to a specific activity on plate tectonics, her conclusion that inquiry-based teaching does not necessarily lead to conceptual clarity is an interesting comment that we did not expect.

Overall, the effect of inquiry-based modeling on student achievement in science as reported by two groups of teachers who have been taught by science faculty in teacher professional development programs are remarkably similar. Teachers see real differences in student motivation and in a number of observable student behaviors. These results are consistent with what might be predicted from Social Learning Theory, where imitation is found to be a powerful strategy for learning (Bandura, & Walters, 1963; Bandura, 1977).

Our results support continued efforts to implement teacher development programs where the participants experience inquiry-based, hands-on teaching for themselves, along with supporting materials to assist them in conducting the activities with their own students.

We note that teachers also reported gains in standardized test scores and this finding merits more investigation, especially in an environment driven by test score results. In our estimation, these results dispel the myth that students will not achieve in a content-driven environment or pass standardized tests unless direct instruction is frequently implemented. The results, as reported by participants in response to the survey, support our view that teachers who implement inquiry-based science activities once a week or even less than once a week have seen observable gains in student achievement.

Conclusion and recommendations

More insight into the relationship between science faculty modeling of inquiry teaching in professional development programs such as the Hollins and Sweet Briar projects might be gained from structured interviews of a random sample of teachers who were participants. Also helpful could be teacher classroom behavior assessments to determine changes in teaching methods employed by the teachers after the project interventions.

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Appendix

Eisenhower Program-Sponsored Project Participant Survey

Please answer the following questions by circling the response that best describes your experience. In some cases, you will be asked to write a response. Please feel free to use the back of the survey to complete your statement. Thank you!

1. How frequently have you used inquiry-based activities in your science teaching since your Eisenhower experience?

(a) not at all
(b) less than once a week
(c) once a week
(d) more than once a week

2. How has inquiry-based teaching affected student achievement in your classroom?

(a) No observable differences have been noted.
(b) Some gains have been observed.
(c) Moderate gains have been observed.
(d) Large gains have been observed.

3. If you indicated in question 2 that gains in student achievement have been observed, which performance indicators have shown improvement? Check all that apply.

____ Performance on teacher-made exams
____ Student assignments, like homework
____ Student projects
____ Standardized tests results
____ Hands-on classroom activities
____ Student problem-solving in the classroom
____ Student recall of content
____ Other (please state)____________

Briefly explain your choices, citing relevant evidence that you have found to support your choices:

____

____

____

4. If you observed negative effects of inquiry-based teaching on student achievement, which performance indicators would you choose from the list? Check all that apply.

___ Performance on teacher-made exams
___ Student assignments, homework
___ Student projects
___ Standardized test results
___ Hands-on activities in the classroom
___ Student problem-solving activities
___ Student recall of content
___ Other (please state)____________

Briefly explain your choices, citing relevant evidence that you have found to support your choices:

____
____
____
____

5. How has inquiry-based teaching affected student motivation in your classroom?
(a) No observable differences have been noted.
(b) Students are less receptive/responsive to learning.
(c) Students are more receptive/responsive to learning.

Briefly explain your choice, citing relevant evidence to support your observations.

____
____
____

6. Summarize the effects of inquiry-based teaching on student achievement in your classroom. Please take this opportunity to tell us about any effects that were not listed in the survey either positively or negatively.

____
____
____

7. We would like to ask the following questions for demographic purposes:

(a) How long have you been a teacher? ________________

(b) Are you an elementary, middle, or secondary teacher? ________________________

(c) In the past five (5) years, have you participated in any other professional development activities – courses or workshops – specifically focused upon inquiry teaching? ________

If yes, can you please identify such activities? ________________________________
____
____
____

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Should you have further questions, please contact me at 1-800-822-9229; or E-mail: lkelly@aacte.org.

Sincerely,

Linda M. Kelly
Acquisitions and Outreach Coordinator

AACTE
AMERICAN ASSOCIATION OF COLLEGES FOR TEACHER EDUCATION
1307
NEW YORK AVE., NW
SUITE 300
WASHINGTON, DC
20005-4701
202/293-2450
FAX: 202/457-8095